Measuring Low X-ray Surface Brightness at High Redshift

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(with a few extra on the XRS background added)

- Cluster photometry to the virial radius
- Surface brightness sensitivity limits
- Implications for mission requirements

Constellation-X and Clusters

- Clusters are more complex than we'd like:

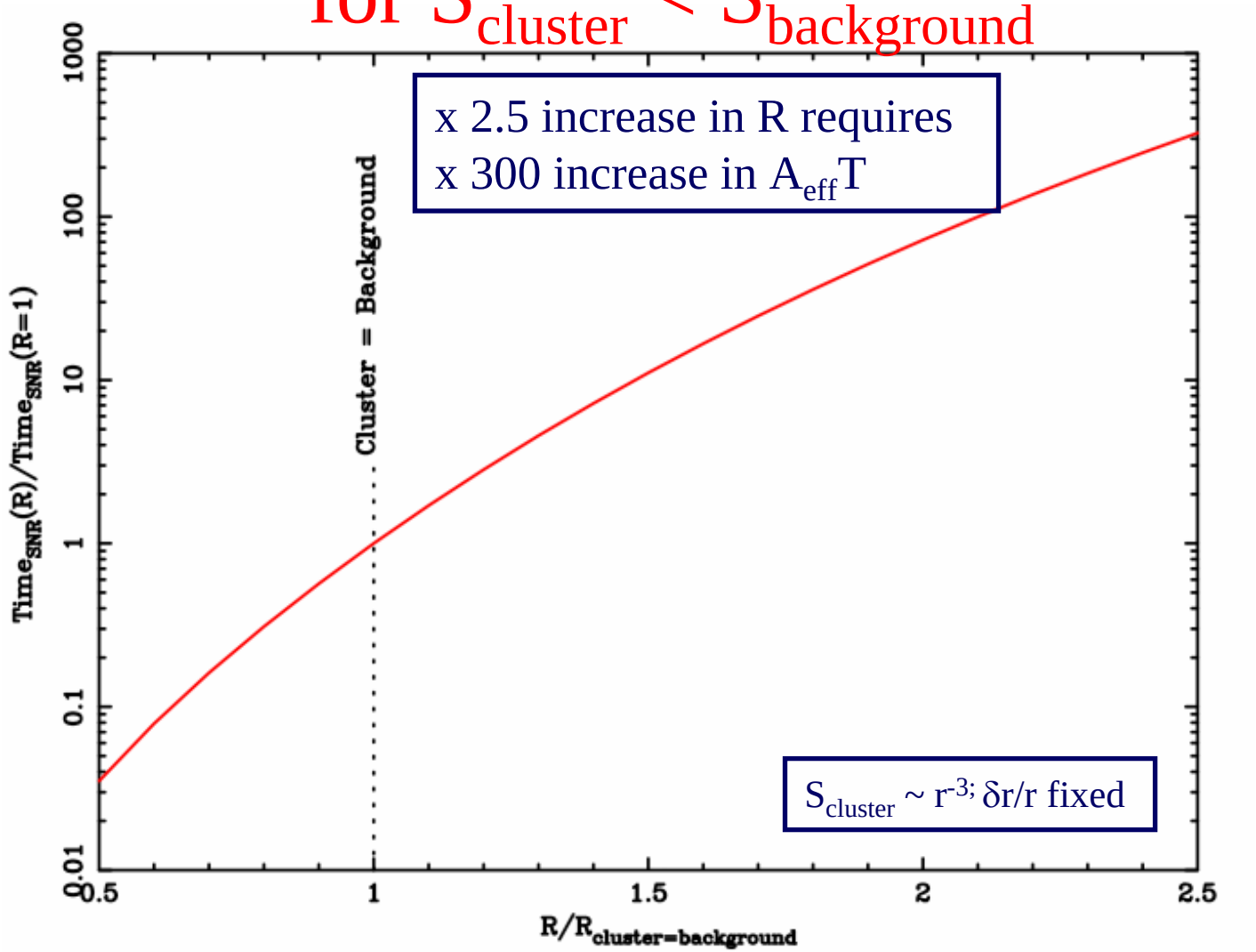
  Non-gravitational physics is important (from scaling laws & their evolution)
- We need to understand clusters at the epoch at which we want to use them (z ~ 1) to study dark energy
- Con-X must allow us (in conjunction with lensing and SZ data) to model these objects as completely as possible.

Surface Brightness Limits

- Rest-frame surface brightness $\sim L/r_v^2 \sim [M_v E^2(z)]^{2/3}$
  - From self-similarity ($E(z) = H(z)/H_0$)
  - Non-gravitational processes will reduce this
- Typical Chandra limits at $z \sim 0.4$, $M \sim 3 \times 10^{14} M_{sun}$
  - Photometry to $\sim r_{300}$ (e.g., Vikhlinin)
  - Spectroscopy (kT) to $\sim r_{2500}$ (e.g. Allen)
- Goals: Spectroscopy to $\sim r_{200}$ at $z > 1$, $M < 10^{14} M_{sun}$
- Requires surface brightness limit reduction by factor > 65!

Is this possible?

Integration Time Rises Rapidly for $S_{cluster} < S_{background}$



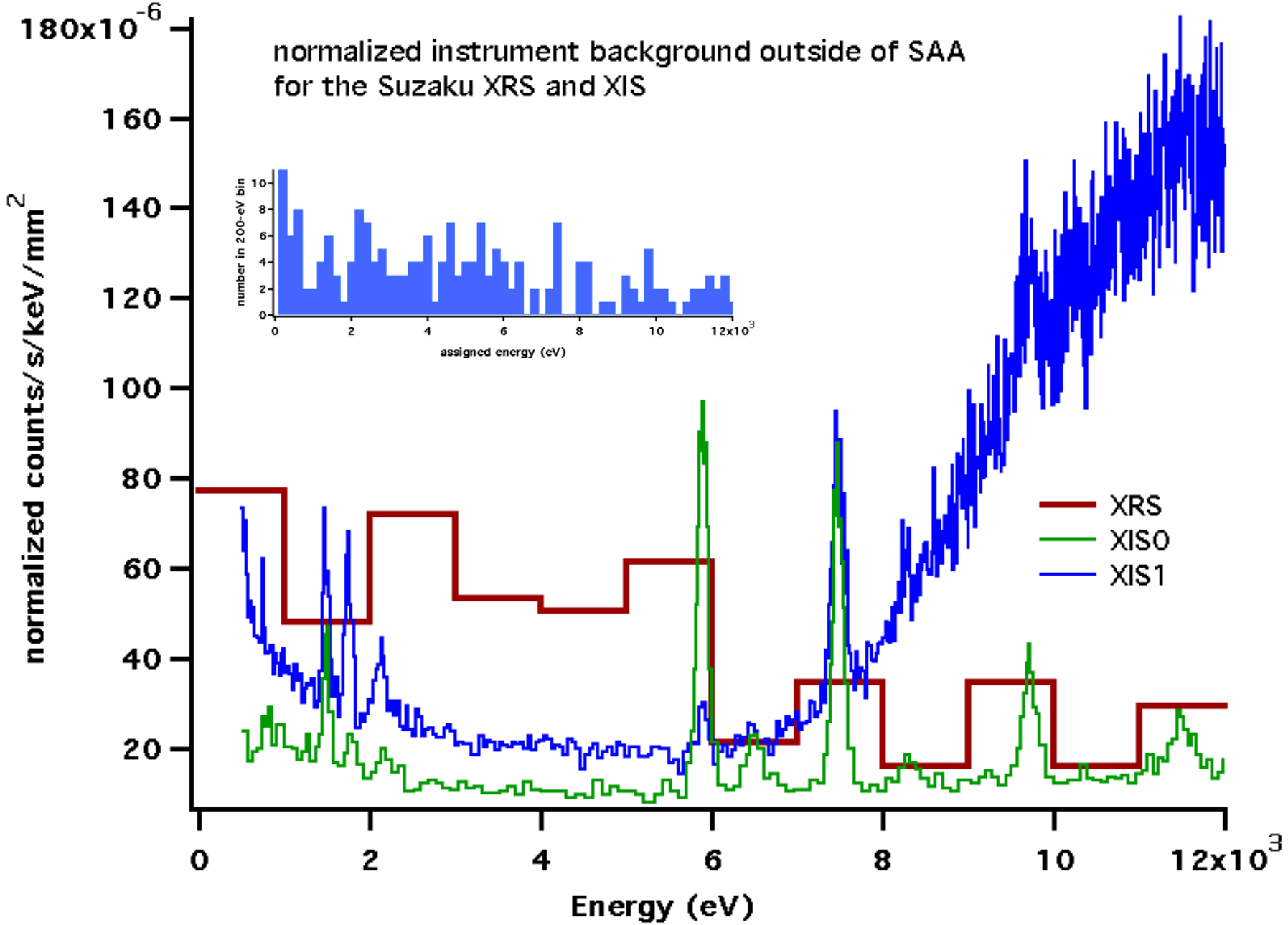
(Detector Limited)

Surface Brightness Sensitivity

$$S_{min}\ (c\ s^{-1}\ cm^{-2}\ ster^{-1}) \sim B_{det}(c\ s^{-1}\ cm^{-2})\ F^2/A_{eff}$$

Mission	F (m)	A_{eff} (m^2)	B_{det} (1 keV) ($c\ s^{-1}\ cm^{-2}\ keV^{-1}$)	F^2/A_{eff} (rel. to CXO)	S_{lim}** (rel. to CXO)
CXO	10	0.07	10^{-2}	1	1
XMM (Epic PN)	7.5	0.15	2×10^{-2}	0.26	0.52
Suzaku XIS (1 sensor)	4.75	0.04	1.2×10^{-3}	0.39	0.05
Con-X (classic, 1 module)	10	0.375	1.5×10^{-2} (scaled from XRS)	0.19	0.29
XEUS	50	6	1.5×10^{-2} (?)	0.29	0.45??

** *Source = Particle Background (Ignores Galactic Foreground!)*


normalized instrument background outside of SAA
for the Suzaku XRS and XIS
number in 200-eV bin
assigned energy (eV)
normalized counts/s/keV/mm^2
Energy (eV)
XRS
XIS0
XIS1
180x10^{-6}
160
140
120
100
80
60
40
20
0
2
4
6
8
10
12x10^3

(Detector Limited)

Surface Brightness Sensitivity

$$S_{min}\ (c\ s^{-1}\ cm^{-2}\ ster^{-1}) \sim B_{det}(c\ s^{-1}\ cm^{-2})\ F^2/A_{eff}$$

Mission	F (m)	A_{eff} (m^2)	B_{det} (1 keV) ($c\ s^{-1}\ cm^{-2}\ keV^{-1}$)	F^2/A_{eff} (rel. to CXO)	S_{lim} ** ($ph\ s^{-1}\ cm^{-2}\ keV^{-1}$)
CXO	10	0.07	10^{-2}	1	14
XMM (Epic PN)	7.5	0.15	2×10^{-2}	0.26	7.4
Suzaku (1 XIS)	4.75	0.04	1.2×10^{-3}	0.39	0.7
Con-X (classic, 1 module)	10	0.375	1.5×10^{-2} (?)	0.19	3
XEUS	50	6	1.5×10^{-2} (?)	0.29	6??

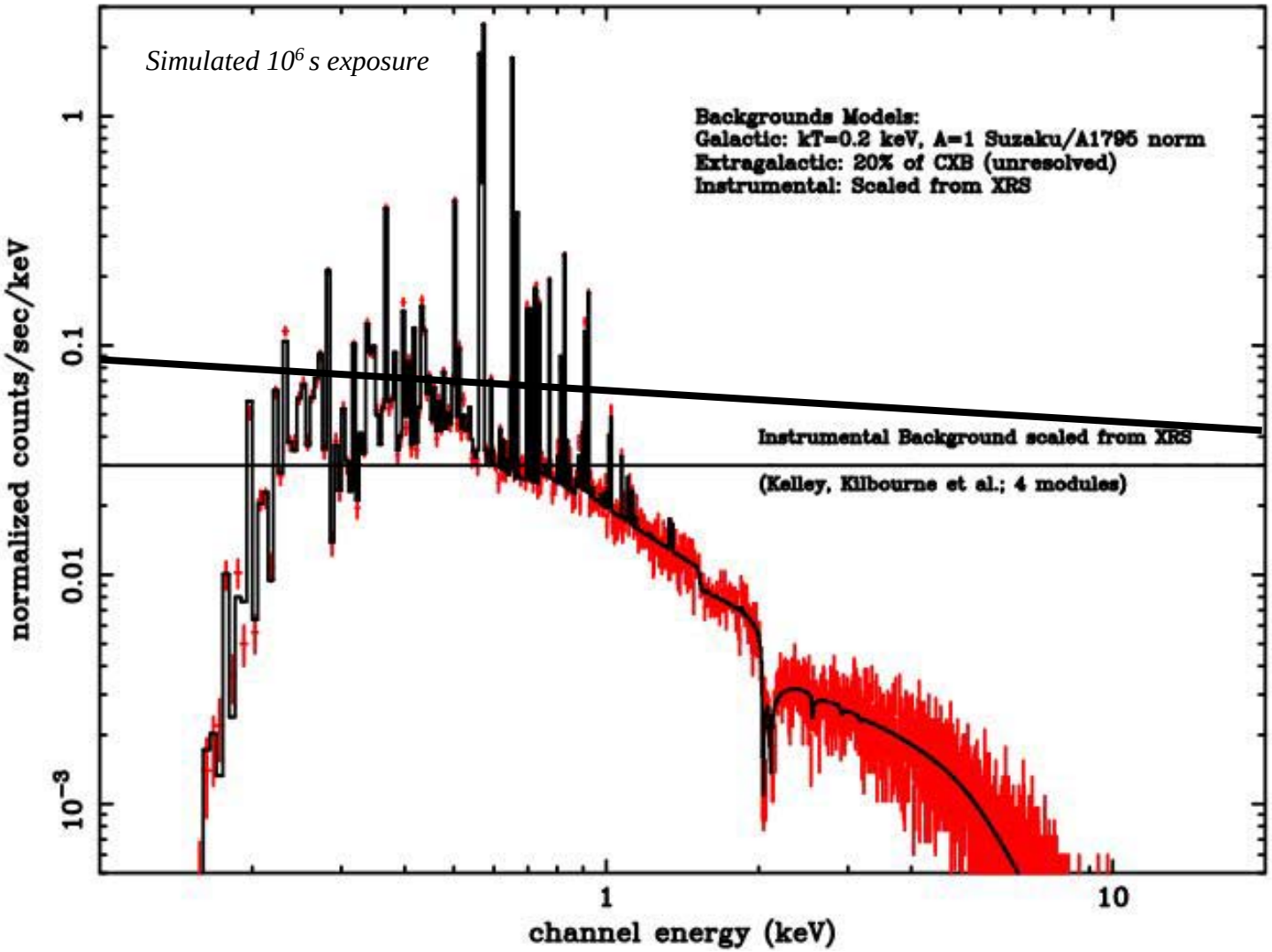
** *Source = Particle Background (Ignores Galactic Foreground!)*

Rates over Con-X FOV

- 4, 32x32 arrays = 2.56 cm^2
- Using 0.015 c/s/keV/cm^2 (3x0.005), get 0.038 c/s/keV. But XRS background wasn't flat. Use 0.007 to characterize soft part of band. Increase LEO-to-L2 scaling to 5. Then get 0.09 c/s/keV.

Constellation-X Backgrounds

2.5 x 2.5 arcmin FOV



Summary

- Constellation-X must validate physical models of z~1 clusters
- This will entail spatially resolved spectroscopy to r_{vir} & surface brightness sensitivity 50x XMM's
- XRS flight data provide secure basis for Constellation-X background estimates
- Instrumental & cosmic backgrounds pose significant challenges; lower (still) instrumental background is highly desirable.